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THE
CAUSE OF THE GLACIAL PERIOD,

WITH REFERENCE TO THE BRITISH ISLES.

BY
CHARLES RICKETTS, M.D., F.G.S.

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January 5, 1879. — note
a pamphlet expressing a theory
invented to account for a
theory. I deny that there
is evidence of a general
glacial period. It is futile
to account for it. J.R.

THE CAUSE OF THE GLACIAL PERIOD,

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CHARLES RICKETTS, M.D., F.G.S.

IT is a fact universally accepted that, within a period comparatively recent, extensive districts in North America and in Europe, now fruitful and luxuriant, were covered with a thick mantle of snow and ice; and their valleys were filled with glaciers, which extended into the sea, and, breaking off at their extremities, floated away as icebergs.

The causes which produced a temperature of such severity, as the evidences upon which this opinion has been founded indicate, have excited much speculation. The theory which of late has found most advocates is that proposed by Mr. Croll:—That the winters during this, the Glacial Period, happened in aphelion, when, as a result of a greatly increased eccentricity of its orbit and the precession of the Equinoxes, the Earth was eight and a half millions of miles further distant from the Sun during winter than it is at present; that therefore the winters would have been longer and the cold more intense; that the North Polar regions were entirely covered with a thick capping of ice, so great that the accumulation caused a displacement of the Earth's centre of gravity; and to this cause he attributes the submergence of the land which is constantly found where evidences of glaciation have been observed. He also justly concludes that the so invariable occurrence of submergence along with glaciation points to *some* physical connexion between the two. But the submergence of Greenland, beneath its present rapid accumulation of snow, cannot be referred to such a cause as a change in the Earth's centre of gravity, for at the same time and in about the same latitudes—in Norway and Spitzbergen—the land is rapidly rising. It seems not improbable that the recent recession of the glaciers in Norway may account for the rise of land there, in consequence of the removal of pressure, and, to a similar cause, its occurrence, subsequent to the Glacial Period, may be attributed.

I have elsewhere (GEOL. MAG. Vol. IX. page 119) attributed this subsidence during the Glacial Period to the effects of the pressure which this increased mass of snow would have in forcing downwards

¹ A paper read before the British Association (Section C.) at Bristol, August, 1875.

the crust of the earth into its fluid substratum; basing my opinion,—upon the constant occurrence during all geological time of evidences of subsidence and accumulation co-existing in the different formations,—on the existence of bays and of deltas at the mouths of all great rivers, being the submerged and filled-up continuation of their valleys; in the latter the result of artesian borings has proved the occurrence at various depths of evidences of what have been successive land surfaces,—on the depression which took place during the Glacial Period, and the partial re-emergence of the land when it was relieved of its weight of ice and snow,—and on the subsidence recently occurring in Greenland simultaneously with a rapid increase of accumulation of snow.

The occurrence of subsidence of land being due to the pressure of accumulations, though it has been advocated by Sir John Herschel, by Prof. Hall of New York, and by Dr. Dawson of Montreal, appears in a singular manner to have escaped the consideration of geologists; though by this circumstance only can a satisfactory explanation be given of many geological phenomena. Nevertheless, the fact of their simultaneous occurrence is constantly recognized.¹

The relative positions under which the two Poles are placed are so different, that great care must be taken in arguing from the state of one to that of the other. It must not be inferred that because it may be possible that the *land*, situated at the South Pole and surrounded by *water*, is covered with an "ice-cap," that therefore the *ocean*, situated at the North Pole and surrounded by *land*, would be covered in the same way. It appears to be more than doubtful whether, with the existence of an Arctic Ocean having communications open with the Atlantic and Pacific, an "ice-cap" comparable with that covering the land about the Antarctic Pole could by any possibility exist; for before a resting place could be found sufficient to bear such an accumulation of snow, as has been supposed to have at one time existed, the whole sea must have been frozen even to its lowest depths; and that could not take place whilst salt water continues to get denser as it becomes colder, and there is also a free communication between the Polar Sea and the Atlantic.

¹ In the President's Address to the Geologists' Association, Nov. 7th, 1873, Mr. H. Woodward, F.R.S., has objected to the theory of subsidence being the result of accumulation, on the grounds that if in the Bay of Bengal (where, by the artesian borings made in the Delta of the Ganges, the land has been proved to have sunk to the depth of 481 feet and upwards) the sediment deposited has power by gravitation to thus depress the ocean-bed, much more ought the solid mass of the Himalayan range, with its innumerable and lofty peaks, to sink into the yielding crust beneath (GEOL. MAG. 1873). But the areas out of which the Himalayas have been sculptured have, from the commencement of their present denudation, been sustained above the sea-level, and the weight to be supported has diminished, as particle after particle has been removed, the peaks and valleys registering a portion, but by no means the greater amount, of the denudation the mass has undergone; so that the Himalayas, in consequence of the great amount of denudation to which they have been subjected, will not press with so great a weight upon the fluid substratum. But if the sediment brought down by the Ganges and Brahmapootra has caused, by its weight that subsidence which has taken place in the Bay of Bengal, it necessarily follows that the area, forming and supporting these mountains, must rise in accordance with the amount of material removed.

Nor could there have been, during the Glacial Period, any great thickness of snow on the land surrounding the Arctic Sea; for perpetual snow existed as far south as the latitude of New York, and the greater part of Europe was covered with it; the wind passing over a land surface of such extent and having a glacial temperature, would have had almost the whole of its water condensed out of it long before reaching the Arctic Circle. "The wet would be squeezed out by the cold, as water is wrung from a sponge."¹ Even when the winds have to pass over land, the mean temperature of which is considerably above the freezing-point, the air parts with so much of its moisture that at no time, since the Mammoth and woolly-haired Rhinoceros roamed over the plains of Siberia, has there been in Northern Asia so great an accumulation of snow as to form glaciers; otherwise the remains of these animals, found in the banks of the Lena, would have been swept by them into the Arctic Sea; yet during all that time the soil, in which they have been imbedded, has continued so persistently frozen that their remains have been preserved with the soft parts undecomposed.

It does not at all follow that, with diminution of temperature in the Arctic regions, there should also have been at the same time reduction of the winter temperature of the British Isles. The present temperate and equable climate of Britain is dependent on the warmth of the waters which, derived partly from those of the Gulf Stream and at a lower temperature from those of the Temperate Zone, are carried as a set or current towards the Polar regions; and, being many degrees higher than would otherwise be the mean annual temperature of the British seas, modify also the temperature of the air passing over them.

Dr. Carpenter has, as I believe, demonstrated that what I will call the North Polar Current (termed in Johnston's Physical Atlas, "North-East Branch of the Gulf Stream") is dependent on the effects which diminution of temperature in the Polar regions has in causing the displacement by sinking of the surface water of the Arctic Sea, the density of which has been increased by the temperature being diminished, and the necessary influx of lighter water, that is, the comparatively warm water derived from the Gulf Stream and the Temperate Zone, to replace the colder which has subsided.

The North Polar Current thus produced, and consisting of water very much warmer than the surface temperature of the North Atlantic would be, if this current did not exist, supplies heat and moisture to the atmospheric currents passing over it; so that partly on this account, and partly from the inability of heat to radiate so readily from the surface of the land in consequence of the frequent cloudiness of the sky, the winter temperature of Britain is considerably milder than it would be under different conditions; whilst in summer it is often modified by the difficulty with which the sun's rays can penetrate when, from the same cause, there is an excess of cloud or vapour in the atmosphere. If the peninsula of Florida did not exist, the winter temperature of Britain would be still

¹ J. F. Campbell, F.G.S. "Frost and Fire."

milder, as, in consequence of it, the Gulf Stream has to traverse a distance of several hundred miles more than would be the case otherwise.

Changes of climate are now taking place for which I can imagine no adequate cause, excepting the reckless destruction of the great American forests. The temperature of Iceland and of Greenland is much more rigorous than when they were first discovered;¹ whilst, upon the other hand, the glaciers of Norway are receding, and the Christmas of tradition visits us at very distant intervals. Even temporary changes as indicated in North America appear to influence our winters; thus of late years the most severe winters there, such as those of 1872-73 and 1873-74, were with us remarkable for their mildness. The opposite conditions have also been noticed; such as occurred during the Russian War in 1854-55, when the frost on the Eastern shores of the Atlantic was intense, whilst the winter was mild in Northern America. It has been stated that "it is a saying amongst the Danes that there is mild weather in Iceland when it is cold in Europe, and *vice versa*."²

Previous to the Glacial Period there existed a very different contour of the North American continent from the present. The Gulf of Mexico extended over what is now the valley of the Mississippi, even to St. Louis, upwards of 600 miles north of New Orleans; the peninsula of Florida was submerged; and along the east coast a very considerable belt of land, extending to the Alleghany Mountains, was sunk below the level of a sea whose waters were of a tropical temperature. Such a variation in the coast-line must have had a great effect upon the climate. With a Gulf of Mexico extending 9° farther north than it does at present, the air, heated and charged with moisture derived from its tropical waters, would have been directed up the valley of the Ohio by the western flanks of the Appalachian chain, and have modified the climate even of extreme northern districts. Florida presenting no obstruction, the Gulf Stream must have been impelled many degrees further northwards by the *vis a tergo*—the N.E. and S.E. trade-winds—carrying a larger quantity of Equatorial water than it now conveys, namely, that which is deflected round the western extremity of Cuba and what escapes over the Bahama banks and channels. Therefore the amount of heat derived from the tropics which was conveyed to high northern latitudes must have been immensely increased. I am not aware whether it is possible to co-ordinate those beds abounding in plant-remains, which have been discovered in Greenland, in Iceland, and in Spitzbergen, with those indicating these changes in the coast-line of America; but such alterations must have induced a condition of temperature at all events nearly approaching, if not similar to, that which these plant-remains indicate.

As the present state of the winter temperature of Britain depends on the volume and warmth of the North Polar Current, the waters of which are, to a considerable extent, derived from those of the

¹ A Visit to Iceland. By Madame Ida Pfeiffer. Page 64.

² Iceland: its Scenes and Sagas. By S. Baring-Gould. Page xxxi.

Gulf Stream, it follows that any serious diversion of this stream would affect our climate in an opposite direction.

There are two areas in the isthmus which separates the Atlantic from the Pacific where a comparatively slight depression would cause the two oceans to mingle. The Panama Railway cuts through a ridge which is 299 feet above the sea-level;¹ and, near Lake Nicaragua, the lowest pass is 133½ feet above the sea,² whilst the isthmus nowhere attains the height of 1000 feet.³ Should depression take place so as to submerge these areas, there would be no impediment to the Atlantic Equatorial waters passing into the Pacific Ocean, for the mean height of the former is somewhat greater than that of the latter—that is, it is somewhat banked up by the action of the trade-winds.

In considering the West Indian Islands as the remains of a submerged part of the continent of South and Central America, Mrs. Somerville has given the true explanation of the formation of the Gulf of Mexico; but the depression by which they have been formed has extended to a greater depth than the present. In Jamaica the Tertiary strata are more than 5000 feet thick,⁴ and Santiago in San Domingo, situated 2000 feet above the sea, rests on Tertiary strata.⁵ The whole valley of the Mississippi to beyond its junction with the Ohio once formed a portion of the Gulf of Mexico, the land having sunk considerably below its present level.

Former depression has also taken place along the western coast. Professor Newberry observed a sea-beach, containing shells similar to those now existing in the ocean below, at 80 or 90 feet above high-water mark, and also at a still greater elevation;⁶ and the Gulf of California is but a submerged extension of the valley of the Colorado River.

It is not probable that subsidence could have occurred to so great an extent on both its sides without the same process also affecting the isthmus.

The present fauna on the different sides of the isthmus affords indications of a former intercommunication of the two oceans; by the identity of species in some instances, by the similarity in others. Mr. Philip P. Carpenter (British Association Report, 1856) regards 35 species of shells as identical in the two oceans; 34 species are so nearly allied that they may prove to be identical; and 41 species really separated but by very slight differences only. Professor Wyville Thomson, in "Depths of the Sea," arranges side by side 18 Echinoderms from each sea, "which resemble one another so closely in habit and appearance as to be at first sight hardly distinguishable."

¹ Admiralty Chart.

² The Naturalist in Nicaragua. By Thos. Belt, F.G.S. Page 35.

³ Tertiary Beds in St. Domingo. By T. S. Heuken. Quart. Journ. Geol. Soc., vol. vi. p. 44.

⁴ Notice of the Geology of Jamaica. By P. M. Duncan, M.B., Sec. G. S., and G. P. Wall, F.G.S. Quart. Journ. Geol. Soc., vol. xxi. pp. 5 and 6.

⁵ On Tertiary Beds in San Domingo. From Notes by T. S. Heuken. Quart. Journ. Geol. Soc., vol. vi. page 39.

⁶ Colorado Exploring Expedition.—Geology. By Dr. J. S. Newberry. Page 12.

There have been few, if any, investigations made for the purpose of determining the question, but these evidences are almost conclusive that submergence of the isthmus has taken place so as to permit the waters of the two oceans to mingle. If it has occurred to any considerable extent, it must necessarily have progressed in an increasing ratio, unless there were any counteracting forces brought into action; for the causes which induced it would still have been in operation; sediments brought down by the Amazon and Orinoco would still have been carried into the Caribbean Sea, and in much greater quantities, for the Equatorial Current, meeting with no obstruction at the isthmus, would have been propelled with greater celerity by the trade-winds; whilst such portions of the sediments from the Mississippi, as are now carried towards Florida, would have been deposited in the Gulf, and, if the winter climate in the north increased in severity, the amount of these deposits would be augmented, as the frost would disintegrate the rocks more rapidly, and in a greatly increased ratio, if the land was covered with glaciers.

If the temperature of our island can be influenced in any appreciable degree by changes of temperature affecting the Arctic Ocean, the winter temperature would be lowered to an immensely greater extent should any considerable volume of Equatorial water be diverted across the supposed submerged isthmus, for the hottest of the water would pass into the Pacific Ocean; whilst according to the size and depth of this diverted current, the Gulf Stream in the Atlantic would become less and less, in consequence of the diversion of that force by which it was impelled forward.

With an indentation of Central America similar to the present, there could, under no circumstances, have been the same amount of warmth conveyed to such high southern latitudes by the Brazilian Current as now passes to the north by the Gulf Stream, for, not only the whole of the northern division of the Equatorial Current must have been propelled into the Caribbean Sea, but a considerable amount of the southern division also, from which, on account of the obstruction caused by the south-east trade-winds, there would be no method of escape southwards, and therefore it must have been borne towards the north, as it is now by the Gulf Stream. But should there have been depression of the isthmus, not only would there have been, as we have seen, reduction of temperature in the North Atlantic, but in the South Atlantic also; for if it were not for the obstruction caused by the isthmus, the power and extent of the Brazilian Current would be much decreased, in consequence of the greater portion, and that the hottest, of the southern division of the Equatorial Current continuing onwards past Cape St. Roque, so much of it not being deflected along the east coast of South America as there is now.

If this submergence of the isthmus has taken place, and it is the necessary result of those changes which were in progress during the Tertiary Period, the extension of the Gulf of Mexico northward would still have continued, as it did then, far into the interior of the continent; but with the deflected Equatorial Current it would

no longer be supplied with water of a tropical temperature, but would have had the normal temperature of the latitude, and even this would have been greatly diminished by the glacial coldness of the waters brought down by the Mississippi and the Ohio.

With the removal of the Gulf Stream the North Polar Current could have had no higher temperature than that which it derived from the Temperate Zone, thus greatly intensifying the cold, so that the moisture which the atmosphere contained would have been condensed out of it in the form of snow in much lower latitudes than at present, probably forming a great ice-barrier across the northern extremity of the North Atlantic. With such an extensive field of ice between the Atlantic and Arctic Oceans it is improbable that sufficient water could remain in the atmosphere to admit, within the area of the latter, sufficient precipitation to form ice-floes as extensive, or as thick, as occur there now.

With the British Isles covered with a great thickness of snow, and with glaciers coming down to the sea, it may be presumed that the southern limits of the ice-drift might have ranged from somewhat south of 50° N. to about 60° N. near the longitude of Iceland; but an extensive frozen area, such as it would have formed, would condense the water contained in the atmosphere, so that, upon the supposition that there exists an open Polar Sea where our Arctic explorers expect to find it, the ice-floe caused by its precipitation could then have hardly extended much farther northward than the latitude of North Cape, the most northern point of Norway, and beyond it there would probably have been an open Polar Ocean.

Prof. Geikie and Mr. James Geikie have shown that in Scotland there are evidences which demonstrate the occurrence of a succession of Glacial Periods, having intervening times characterized by a mild and even genial climate. These intercalated temperate periods have been considered to be indirectly due to the precession of the Equinoxes, which during a period of extreme eccentricity would gradually have caused the supposed ice-cap to shift from one pole to the other. The occurrence of a succession of depressions and upheavals of Central America, causing communications and separations of the two oceans, would certainly cause the same phenomena to take place, and might not only account for these interposed Glacial Periods, but also for the occurrence of shells having a boreal character during intervals in the Tertiary Period. It is a circumstance not unlikely to have happened, but of which we have no absolute proof; nor has any evidence of it been sought for. Temporary upheavals and subsequent depression have been not unfrequent both during the deposit of Palæozoic as well as more recent formations.

Mr. P. P. Carpenter has suggested that the intercommunication between the two oceans may have been correlative with the glacial conditions in European seas; whilst others, and none more clearly than Messrs. Croll and Geikie, have demonstrated how immensely the temperature of the North Atlantic would be diminished by the removal of the Gulf Stream, causing "Scotland to experience a

climate as severe as that of Labrador, while the greater part of Norway would be uninhabitable.”¹

It has now, I think, been proved that, with the present contour of the shores of the North Atlantic, the occurrence of extreme cold, dependent on the winters occurring when the earth is at its greatest distance from the Sun, and during great eccentricity of its orbit, is inadequate to cause glacial conditions in the British Isles and Eastern Europe. The same reasoning which has been used to demonstrate it will also apply to their occurrence as a consequence of a *supposed* increase of the obliquity of the Ecliptic.² The diversion of the Gulf Stream is upon all hands considered sufficient to produce all those effects which occurred in Britain during the Glacial Period; and there are many evidences which tend to prove that subsidence of the isthmus has taken place, so as to allow of this change in the direction of the Equatorial Current, but, to obtain absolute proof, it is requisite that investigations, with this object in view, be made in Nicaragua and other parts of Central America.

¹ Mr. James Geikie, “Great Ice Age.”

² Climate of the Glacial Period. By Thomas Belt, F.G.S. Quart. Journ. of Science, 1874, page 461. Variations in the Obliquity of the Ecliptic. By Colonel A. W. Drayson, F.R.A.S. Quart. Journ. of Science, 1875, page 279.

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